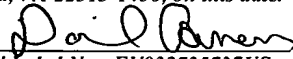


PATENT APPLICATION COVER SHEET
Attorney Docket No. 1503.68783

I hereby certify that this paper is being deposited with the United States Postal Service as EXPRESS MAIL in an envelope addressed to: Mail Stop PATENT APPLICATION, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on this date.

Dec. 5, 2003
Date


Express Mail Label No.: EV032735737US

WRITE PRECOMPENSATION AMOUNT
SETTING METHOD AND APPARATUS

INVENTOR:

Hidetake YAMANOUCHI

GREER, BURNS & CRAIN, LTD.
300 South Wacker Drive
Suite 2500
Chicago, Illinois 60606
Telephone: 312.360.0080
Facsimile: 312.360.9315
CUSTOMER NO. 24978

APPLICATION FOR
UNITED STATES LETTERS PATENT
SPECIFICATION

INVENTOR(S): Hidetake YAMANOUCHI

Title of the Invention: Write Precompensation Amount Setting
Method and Apparatus

**WRITE PRECOMPENSATION AMOUNT SETTING METHOD AND
APPARATUS**

Cross Reference to related application

5 This application is a continuation of
international PCT application No. PCT/JP01/05906 filed
on July 6, 2001.

Background of the Invention

10 **Field of the Invention**

 The present invention relates to a write
precompensation amount setting method and apparatus,
which tune a write precompensation amount of a magnetic
disk device, and more particularly, to a write
15 precompensation amount setting method and apparatus for
reducing a compensation shift which becomes problematic
in a magnetic disk device.

Description of the Related Art

20 When magnetically recorded digital data is
reproduced with a magnetic head, a peak shift occurs
on a reproduced waveform. This peak shift is caused by
a mutual interference with an adjacent bit (magnetized
region) when a magnetized region corresponding to a bit
25 array is read with a magnetic head. If the peak shift

increases, a read pulse cannot be obtained at a position determined by a data window, which leads to a read error. The peak shift of this type is not too problematic when a recording density is low, but is problematic when the recording density is high. A method of compensating for a peak shift is a tuning method where the phase of a pre-identified bit, when data of a particular bit array whose peak shift is problematic, is recorded. In other words, a method compensating for a write operation (write precompensation).

Conventionally, a write precompensation amount according to an environmental temperature is determined at an ordinary temperature for each head as a drive parameter, and uniformly set for each environmental temperature in normal cases.

Fig. 1 is a flowchart showing the conventional process for setting a write precompensation amount.

Firstly, error rates are measured at ordinary and low temperatures in a test drive (step S1). For example, respective error rates are measured when a write precompensation amount at an ordinary temperature (such as 25 degrees centigrade) with a write current 40 mA, and a write precompensation amount at a low temperature (such as 5 degrees centigrade) with a write current 50 mA are changed between 15 and 30% in steps of 1%.

Next, the write precompensation amounts at the best (minimum) error rates among the error rates measured in step S1 are determined as optimum write precompensation amounts at the ordinary and the low
5 temperatures in the test drive (step S2). For example, if the write precompensation amounts at the lowest error rates at the ordinary temperature of 25 degrees centigrade and the low temperature of 5 degrees centigrade are respectively 20 and 24%, a deterioration
10 amount from 25 to 5 degrees centigrade is determined to be 4%.

Then, an error rate at an ordinary temperature is measured at the time of mass production (step S3). By way of example, each error rate is measured when the
15 write precompensation amount at the ordinary temperature of 25 degrees centigrade with the write current 40 mA is changed between 15 and 30% in steps of 1%.

Furthermore, the write precompensation amount at
20 the lowest error rate among the error rates measured in step S3 is determined to be an optimum write precompensation amount at the ordinary temperature at the time of mass production (step S4). For example, the write precompensation amount at the lowest error rate
25 at the ordinary temperature of 25 degrees centigrade

is determined to be 20%.

Lastly, an optimum write precompensation amount at a low temperature is set according to the deterioration amount determined in steps S1 and S2 at the time of mass production (step S5). By way of example, the deterioration amount of 4% from 25 to 5 degrees centigrade, which is determined in step S2, is added to the write precompensation amount of 20% at the lowest error rate at the ordinary temperature of 25 degrees centigrade, so that the write precompensation amount at the low temperature is set as 24%.

However, the environmental temperature characteristic of each magnetic head may vary. Actually, a magnetic head whose write characteristic deteriorates significantly at a low temperature requires a large write precompensation amount. Therefore, a lack of compensation occurs. At the same time, for a magnetic head whose write characteristic is good at a low temperature, over-compensation occurs. Namely, any heads whose characteristics shift from an average head characteristic can possibly cause error rate deterioration. This loss cannot be ignored toward future improvements in the performance of a magnetic disk device, and more accurate tuning has been demanded.

Summary of the Invention

The present invention aims at providing a write precompensation amount setting method and apparatus that can optimize the write precompensation amount of a magnetic disk device at the time of mass production, and can reduce a compensation shift which becomes problematic in a magnetic disk device, in view of the above described problems.

The write precompensation amount setting method and apparatus according to the present invention comprise a function detecting respective head characteristics with electric currents used at ordinary and irregular temperatures, and a function setting an optimum write precompensation amount at a low temperature according to the detected head characteristics.

According to the present invention, a write precompensation amount with accuracy higher than that of a conventional technique can be determined by correcting a write precompensation amount according to the characteristics of normal and irregular currents, and by determining the write precompensation amount.

In this case, one example of an irregular current is a current higher than that used at an ordinary temperature.

Another example of an irregular current is a current lower than that used at the ordinary temperature.

Additionally, the precompensation amount of each
5 head with a current lower than that used at the ordinary temperature is obtained, and a write precompensation amount at a low temperature can be also obtained according to the above described precompensation amount.

10 Furthermore, the precompensation amount of each head with a current higher than that used at the ordinary temperature is obtained, and a write precompensation amount at a low temperature can be also obtained according to the above described precompensation
15 amount.

Still further, an example of the head characteristic is a NLTS (Non-Linear Transition Shift) characteristic.

20 **Brief Description of the Drawings**

Fig. 1 is a flowchart showing the conventional process for setting a write precompensation amount;

Fig. 2 shows the dependency of the NLTS characteristic of a normal head on a write current;

25 Fig. 3 shows the dependency of the NLTS

characteristic of a head whose low temperature characteristic is poor on a write current; and

Fig. 4 is a flowchart showing the process for setting a write precompensation amount, according to
5 the present invention.

Description of the Preferred Embodiments

Hereinafter, a preferred embodiment according to the present invention is described with reference to
10 Figs. 2 to 4.

The characteristic of a magnetic head at an environmental temperature has a very close relationship with a change in the characteristic of the magnetic head, which depends on a write current.

15 Fig. 2 shows the dependency of the NLTS characteristic of a normal head on a write current.

A write precompensation amount at a low temperature with a write current W_{L1} mA is determined to be $C_{L1}\%$ (to which a uniform addition amount of $C_{L1}-C_{N1}\%$
20 is applied) in contrast with a write precompensation amount $C_{N1}\%$ at an ordinary temperature (such as 25 degrees centigrade) with a write current W_{N1} mA. A write precompensation amount always becomes large at a low temperature due to characteristic deterioration.

25 Since this is the write precompensation amount

that is determined according to a margin test in a test drive using an average head, it is optimum for the average head.

Fig. 3 shows the dependency of the NLTS characteristic of a head whose low temperature characteristic is poor on a write current.

In contrast to 2, Fig. 3 shows the write current characteristic of the head whose low temperature characteristic significantly deteriorates. In this figure, a write precompensation amount at a low temperature with a write current W_{L1} mA is determined to be $C_{L2} = C_{N2} + (C_{L1} - C_{N1})\%$, to which the uniform addition amount is applied, in comparison with a write precompensation amount $C_{N2}\%$ at an ordinary temperature with a write current W_{N1} mA. However, this is not an optimum write precompensation amount. The optimum precompensation amount is $C_{L2}'\%$.

For such a head, the characteristic of a low (or high) current significantly deteriorates in comparison with the characteristic of a normal current at an ordinary temperature. In this case, for example, the NLTS value of a write current $W_{L2} (< W_{N1})$ mA (at an ordinary temperature) is poorer than that of a normal current by $N\%$.

Accordingly, for example, $K \times N\%$, which is

obtained by multiplying N by a coefficient, is added, so that the write precompensation amount results in $C_{L2} + K_e \times N\%$. Consequently, the accuracy of the compensation can be improved.

5 Fig. 4 is a flowchart showing the process for setting a write precompensation amount, according to the present invention.

 Firstly, error rates at ordinary and low temperatures are measured in a test drive (step S11).
10 By way of example, respective error rates are measured when a write precompensation amount at an ordinary temperature (such as 25 degrees centigrade) with a write current 40 mA, and a write precompensation amount at a low temperature (such as 5 degrees centigrade) with
15 a write current 50 mA are changed between 15 and 30% in steps of 1%.

 Next, the write precompensation amounts at the best (minimum) error rates among the error rates measured in step S11 are determined to be the optimum
20 write precompensation amounts at the ordinary and the low temperatures in the above described test drive (step S12). For instance, if the write precompensation amount at the lowest error rate at the ordinary temperature of 25 degrees centigrade, and the write precompensation
25 amount at the lowest error rate at the low temperature

of 5 degrees centigrade are respectively 20 and 24%, a deterioration amount from 25 to 5 degrees centigrade is determined to be 4%.

Then, at the time of mass production, an error rate
5 at an ordinary temperature is measured (step S13). For example, each error rate is measured when a write precompensation amount at the ordinary temperature of 25 degrees centigrade with the write current 40 mA is changed between 15 and 30% in steps of 1%.

10 Additionally, at the time of mass production, the write precompensation amount at the lowest error rate among the error rates measured in step S13 is determined to be the optimum write precompensation amount at the ordinary temperature (step S14). For example, the write
15 precompensation amount at the lowest error rate at the ordinary temperature 25 degrees centigrade is determined to be 22%.

Furthermore, at the time of mass production, the NLTS at the ordinary temperature is measured, and a
20 correction value is determined (step S15). For example, the NLTS at the ordinary temperature of 25 degrees centigrade with the write current 40 mA (normally used current), and the NLTS at the ordinary temperature of 25 degrees centigrade with the write current 25 mA
25 (current lower than the normally used current) are

measured. Assuming that the measured results are respectively 14 and 25 %, the correction value is obtained by calculating $(25-14) \div 2.49 \div 4.4$ with the use of these values and a coefficient $K_e (=2.49)$.

5 Lastly, at the time of mass production, an optimum write precompensation amount at a low temperature is determined according to the deterioration amount determined in step S12, and the correction value obtained in step S15 (step S16). For example, the
10 deterioration amount of 4% from 25 to 5 degrees centigrade, which is determined in step S12, and the correction value of 4.4% obtained in step S15 are added to the write precompensation amount of 22% at the lowest error rate at an ordinary temperature of 25 degrees
15 centigrade, so that the optimum write precompensation amount at the low temperature is set as 30.4%.

 The above preferred embodiment is described by using the NLTS characteristic as a head characteristic. However, the head characteristic may be a different
20 characteristic such as a XTALK (crosstalk) characteristic, etc.

 Additionally, a current higher than a normally used current may be used instead of a current lower than the normally used current.

25 As described above, the present invention can take

a variety of configurations within the scope where the gist of the present invention is not deviated, without being limited to the above described preferred embodiment.

5 With the write precompensation amount setting method and apparatus according to the present invention, a write precompensation amount is corrected according to the characteristics of a normal current and a low or high current, and a write precompensation amount is
10 determined, so that the write precompensation amount with accuracy higher than that with a conventional technique can be determined.